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AUTHOR Helgeson, Stanley L.
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ABSTRACT

In 1986, a total of 11 different populations involving more than 1000 schools and more than 20,000 students participated in the Second IEA Science Study (SISS). This digest discusses findings related to curricular patterns and student outcomes. Ratings were done at grades 5, 9, and 12, to ensure that the achievement tests reflected the science curriculum of the countries involved. The three curricular grids which were designed to follow international guidelines were: traditional science domains; applied/integrated science; and science processes, practical skills, and attitudes. The review of student outcomes compares the 1986 results with earlier tests. These comparisons resulted in mixed findings. (CW)

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Stanley L. Helgeson

ERIC Clearinghouse for Science, Mathematics, and Environmental Education
Columbus, Ohio

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1200 Chambers Road, Third Floor
Columbus, Ohio 43212
(614) 292-6717

ERIC/SMEAC Science Education Digest No. 1, 1988

THE SECOND IEA SCIENCE STUDY: DATA RELATED TO PRECOLLEGE SCIENCE IN THE U.S.A.

In 1982 the ERIC Clearinghouse for Science, Mathematics, and Environmental Education produced a digest to inform ERIC users that the United States was again participating in an international study of science education. This 1988 digest reports on some of the data gathered in the Second International Science Study (SISS). A total of 11 different populations involving more than 1,000 schools and more than 20,000 students was investigated as part of the study (Jacobson et al., 1987). Findings related to curricular patterns and student outcomes are discussed.

Curricular Patterns

In order to ensure that the achievement tests reflected the science curricula of the countries involved, science educators rated areas of science content and process as to their coverage in grades 5, 9, and 12 in schools with which the educators were familiar. Following international guidelines, three curricular grids were designed, each containing descriptions of one of the following areas:

1. Traditional Science Domains – Earth Science, Biology, Chemistry, and Physics.
2. Applied/Integrated Science – History and Philosophy of Science, Environment, Technical and Engineering, Rural, and Health Sciences.
3. Science Processes, Practical Skills and Attitudes.

From the results of this procedure a quantified and reasonably precise picture of the intended curriculum in the United States could be deduced (Miller, 1986).

At the fifth-grade level, earth science had the highest mean rating (coverage) of the four traditional science domains, with biology and physics tied for second, and chemistry rated the lowest. The emphasis on earth science in the fifth-grade curriculum was consistent with ratings in most other countries. While there were more biology topics with high ratings, there was more agreement in the ratings for physics. This may suggest that certain blocks or categories of topics were more uniformly included in elementary physical science than in biological science. In addition to receiving the lowest ratings, the pattern of ratings for chemistry topics was the least stable. The low level of coverage may be due to the abstract nature of chemistry. With respect to the Applied/Integrated Science Content, environmental science was rated highest in coverage at the fifth-grade level, ranking equal to earth science and ahead of topics in more traditional biology, physics, and chemistry. In descending order of ratings were health science, history and philosophy of science, technical and engineering science, and rural sciences. At grade 5, environmental science is most often integrated into the science curriculum of general science, life science, or physical science; this is also the case for most other science categories at this level.

The instructional objective that received the highest overall mean rating at the fifth-grade level was "Science Inquiry I – Observing and Measuring," followed by "Knowledge and Comprehension," "Manual Laboratory Skills," and "Attitudes." The order of ratings reported for the fifth grade was fairly consistent with other grade levels. This seems to suggest a "ripple effect" whereby curricular decisions at the high school or college levels filter down through the middle/junior high school and finally are absorbed at the elementary school level (Miller, 1986).

At the ninth-grade level, as at the fifth grade, earth science topics rated highest of the four traditional domains of science, followed by biology, physics, and chemistry. Again, in the Applied/Integrated Sciences, environmental science ranked first, followed by health sciences, history and philosophy of science, technical and engineering science, and rural sciences. Of the instructional objectives, the highest mean rating was for laboratory-related manual skills, but the highest mean scores for individual items were those for "knowledge of specific facts" and "knowledge of scientific terminology." It appears from these data that learning science is still heavily dependent on the ability to recall specific pieces of information (Miller, 1986:43).

The ratings for twelfth graders not taking science were based on their last year of science. Biology rated the highest of the four traditional domains of science, followed by earth science, chemistry, and physics. Environmental science rated first among the Applied/Integrated Sciences, followed by health sciences, history and philosophy of science, and rural sciences. Among the instructional objectives, manual laboratory skills rated first, followed by the basic science skills of observing and measuring, knowledge and comprehension, and attitudes. For twelfth graders taking science during their senior year, ratings were confined to topics within the specialized courses. The greatest agreement among ratings was for biology topics, followed by chemistry, physics, and earth science. There was more variation in the planned curriculum for earth science than in any other traditional science at the upper secondary level. Among the instructional objectives for the specialized sciences, manual laboratory skills was rated first, followed by knowledge and comprehension, and basic science skills of observing and measuring.

It should be noted that relatively large overall gains in the ratings were observed from ninth grade to twelfth grade for such inquiry skills as problem seeking, experiment designing, data interpretation, interpolating, extrapolating, and generalizing conclusions. It appears that there is great emphasis on acquisition of scientific facts, terminology, and concepts in the intended curriculum at all levels, although the emphasis tends to diminish as the level of knowledge grows more abstract. Basic inquiry skills are emphasized heavily at all levels (Miller, 1986).

In examining the data, some indicators of the status of science curricula in the United States emerge. At the upper elementary level (Grade 5), the science program is not standardized to any great extent. The content may include units from one or all of the basic sciences, often organized around themes. Process skills, particularly those associated with basic laboratory experiences such as classification, observation, and measurement of phenomena are considered essential elements of elementary school science and are usually introduced through hands-on activities. At the lower secondary level (Grade 9), the science program usually comprises courses in earth science, general science, physical science, or biological science, or, occasionally, unified science. Laboratory skills are highly stressed in the planned curriculum along with the process skills related to scientific methodology and data gathering. At the upper secondary level (Grade 12), there is greater consensus with respect to content than at the lower secondary. The science curriculum in the twelfth grade is usually a full year of science, most often physics, but may be a second course in biology or

chemistry. The planned curriculum also indicates a high level of process emphasis, in part due to state guidelines which require laboratory work. The cognitive skills most heavily emphasized in curriculum ratings were in the areas of knowledge acquisition of known or accepted phenomena: terminology, laws, concepts, procedures (Jacobson, 1986; Miller, 1986).

Student Outcomes

One of the major interests underlying the SISS was to determine what changes had occurred since the First International Science Study conducted in 1970. By using a number of items from the first study (called "bridge items") in the second study, some comparisons were possible (Chang in Jacobson et al., 1987).

At the fifth-grade level students scored, overall, about the same as their 1970 counterparts. Both the 1986 and 1970 students had higher scores on physical science items than on biological science items, but the gains from 1970 to 1986 were slightly greater in biology than in physical science. The scores of fifth graders in 1986 on process and nonprocess items remained essentially the same as in 1970, but the difference between scores on process and nonprocess items narrowed (Chang in Jacobson et al., 1987). The 1986 achievement scores also showed differences between males and females similar to those in 1970, with boys outscoring girls. However, on a manipulative process test, no significant difference in boys' and girls' scores was found (Humrich in Jacobson et al., 1987). Fifth-grade students' responses to the attitude inventory revealed that they enjoy school, find school challenging, and want to get as much education as they can. With respect to science, they find school science interesting, *not* too difficult, and *not* based on learning too many facts. They also believe that science is important for a country's development, as a way of making the world better for the future, and as a means of improving our standard of living. In summary, the science programs at the fifth grade level seem to have made a positive impact on both science achievement and attitudes toward science in particular and school in general (Doran and Jacobson, 1984:42).

Ninth grade students in 1986 performed significantly lower than students tested in 1970. Both 1970 and 1986 scores were higher on biology items than on physical science items, but the 1986 scores were lower than the 1970 scores for both the biological and physical sciences, with slightly smaller losses in the life sciences. The ninth graders also showed a narrowing of the process/nonprocess gap and, although the 1986 students scored lower on the process items compared with their 1970 counterparts, the decline was less than for the nonprocess items (Chang in Jacobson et al, 1987). Again, boys continued to score better on achievement tests than did girls, with about the same difference in percentage correct as in the 1970 study. However, as was the case for fifth-grade students, there was essentially no difference in scores for boys and girls on a manipulative process test (Humrich in Jacobson et al., 1987). With respect to attitudes, the study showed that "liking science" is highly correlated with achievement in science. The 1986 ninth graders seemed to have a positive view of science. The majority of students found school challenging and wanted to get as much education as they could, findings that suggest a predisposition to study science. Most of the ninth graders believed that all students could learn science and a higher percentage of these students than the 13-year-olds surveyed by NAEP found science to be an enjoyable or interesting subject (49 compared with 32 percent). Yet 46 percent did not believe it necessary to know science to get a good job, a surprising finding when students generally view science as being important. In general, ninth graders had a positive view of science but seemed to become more critical as science began to have more impact on their lives (Jacobson and Doran, 1986).

In order to compare outcomes for students of different grade levels or in different courses, a common set of "anchor" items was included in the tests. On 20 common items, the Grade 9 students had, on average, higher scores by 19 percent than the Grade 5 students. On 15 common items, Grade 12 physics students had a 22 percent higher score than the Grade 9 students. However, the Grade 12 nonscience students had the same mean score as the Grade 9 students. In general, these findings were expected (Doran in Jacobson et al., 1987).

In comparing U.S. twelfth-grade students' achievement with that of students of other countries, the findings are not encouraging. A comparison of students in first-year and second-year courses in biology, chemistry, and physics and of twelfth-grade students not studying science shows lower scores for U.S. students in all areas. Especially considering the selectivity of the second-year courses, the results are disappointing (Doran in Jacobson et al., 1987). However, both twelfth-grade students taking physics and those who were not taking any science outscored their 1970 counterparts. The twelfth-grade scores on process items also improved from the 1970 sample, for both physics and nonscience students (Chang in Jacobson et al., 1987). The sex difference in achievement continues to persist from Grade 5 to Grade 12 and from 1970 to 1986. Although the difference over time has not changed greatly, the gap between boys' and girls' scores tends to widen as students move from elementary to secondary school. With the exception of first-year biology, the gap continues for students in first-year chemistry and physics and increases by about two percent in each subject area for second-year courses (Humrich in Jacobson et al., 1987).

Summary

Student achievement scores indicate mixed results since the first study conducted in 1970, with fifth-grade scores essentially unchanged, ninth-grade scores declining, and twelfth-grade scores improving. However, students show progress in science achievement as they move to higher grade levels. Students are generally more competent at the higher levels of thinking or science processes. They tend to have fairly positive attitudes toward science and toward school and education. Sex differences in achievement, however, continue to persist and tend to increase slightly as students progress through the educational system. Comparisons of U.S. students' performance with that of students of other countries are not encouraging. While some aspects of science education show promise, other areas clearly need attention and concentrated effort.

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Prepared by Stanley L. Helgeson,
Associate Director, Science Education

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